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PATENT COOPERATION TREATY

MAILED 22 OCT 2001

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## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

**(PCT Article 36 and Rule 70)**

| Applicant's or agent's file reference 1279-277 | **FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) | |
|---|---|---|
| International application No. PCT/US99/28449 | International filing date *(day/month/year)* 01 December 1999 (01.12.1999) | Priority date *(day/month/year)* 01 December 1998 (01.12.1998) |
| International Patent Classification (IPC) or national classification and IPC IPC(7): G10L 19/00 and US Cl.: 704/207, 220, 222 | | |
| Applicant THE REGENTS OF THE UNIVERSITY OF CALIFORNIA | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

☑ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of report with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☒ Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 24 May 2000 (24.05.2000) | 04 September 2001 (04.09.2001) |
| Name and mailing address of the IPEA/US<br>Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231<br>Facsimile No. (703) 305-3230 | Authorized officer<br>William Korzuch<br>Telephone No. (703) 305-4700 |

Form PCT/IPEA/409 (cover sheet)(July 1998)

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US99/28449

**I. Basis of the report**

1. With regard to the elements of the international application:*

- [ ] the international application as originally filed.
- [x] the description:
  pages 1-14 as originally filed
  pages NONE, filed with the demand
  pages NONE, filed with the letter of ______.
- [x] the claims:
  pages NONE, as originally filed
  pages NONE, as amended (together with any statement) under Article 19
  pages NONE, filed with the demand
  pages 15-23, filed with the letter of 02 May 2001 (02.05.2001).
- [x] the drawings:
  pages 1-4, as originally filed
  pages NONE, filed with the demand
  pages NONE, filed with the letter of ______.
- [ ] the sequence listing part of the description:
  pages NONE, as originally filed
  pages NONE, filed with the demand
  pages NONE, filed with the letter of ______.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

- [ ] the language of a translation furnished for the purposes of international search (under Rule23.1(b)).
- [ ] the language of publication of the international application (under Rule 48.3(b)).
- [ ] the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- [ ] contained in the international application in printed form.
- [ ] filed together with the international application in computer readable form.
- [ ] furnished subsequently to this Authority in written form.
- [ ] furnished subsequently to this Authority in computer readable form.
- [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- [ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. [x] The amendments have resulted in the cancellation of:

- [x] the description, pages None
- [x] the claims, Nos. 11
- [x] the drawings, sheets/~~fig~~ None

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*
** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

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**V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. STATEMENT

| | | | |
|---|---|---|---|
| Novelty (N) | Claims | 3-10, 12, 14-21, 23-25, 28-34 | YES |
| | Claims | 1, 2, 13, 22, 26, 27 | NO |
| Inventive Step (IS) | Claims | 3-9, 12, 14-21, 23-25, 29-34 | YES |
| | Claims | 1, 2, 10, 13, 22, 26-28 | NO |
| Industrial Applicability (IA) | Claims | 1-34 | YES |
| | Claims | NONE | NO |

2. CITATIONS AND EXPLANATIONS

Claims 3-9, 12, 14-21, 23-25 and 29-34 meet the criteria set out in PCT Article 33(2)-(4) because the prior art does not teach or fairly suggest the specific features of these claims including the method of waveform alignment, temporal weighting, correlation filtering, pitch searching and accumulated weighted distortion.

Claims 1, 2 and 13 lack novelty under PCT Article 33(2) as being anticipated by Kleijn ('595).

Regarding independent claim 1, Kleijn ('595) discloses method step (a): "analysis-by-synthesis of the slowly evolving waveform such that it minimizes or reduces the effect of the non-ideal interpolation of a group of adjacent waveforms" -- quantization of a slowly evolving waveform in an inner layer (column 2, line 52 to column 3, line 5); an outer layer performs analysis-by-synthesis (column 2, lines 36 to 51: Figure 9); the object is to obtain a waveform interpolation coder that reduces the effects of artefacts introduced by incorrect representation of periodicity levels (column 2, lines 18 to 31).

Regarding claim 2, Kleijn ('595) is a speech coding system.

Regarding independent claim 13, Kleijn ('595) discloses a waveform interpolation coder that decomposes the signal into a slowly evolving waveform and a rapidly evolving waveform (column 2, lines 52 to 66); the phase spectra ("dispersion phase") is quantized by an index ranging from 0 to K (column 14, lines 15 to 41); analysis-by-synthesis is performed by the inner layer and the outer layer (column 2, lines 36 to 51: Figure 9).

Please See Continuation Sheet

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## VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

The description is objected to as containing the following defect(s) under PCT Rule 66.2(a)(iii) in the form or contents thereof:

On page 2, line 22, "A novel" should be --a novel--.

On page 9, line 7, "unwarping" should be --unwrapping--.

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## VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the questions whether the claims are fully supported by the description, are made:

Claims 12, 17 to 19 and 21 to 28 are objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claims 12 and 22 to 28 are indefinite for the following reason(s):

In claim 12, the limitation "optionally using accumulated spectrally weighted distortion" is indefinite. Limitations reciting "optionally" are indefinite because it is unclear whether that limitation should be considered as positively recited in the claim or not.

In claim 17, the limitation "optionally some weight associated with their probability" is indefinite. Limitations reciting "optionally" are indefinite because it is unclear whether that limitation should be considered as positively recited in the claim or not.

In claim 22, the limitation "optionally using temporal weighting, and optionally using a switch predictive synthesis filter or predictor" is indefinite. Limitations reciting "optionally" are indefinite because it is unclear whether that limitation should be considered as positively recited in the claim or not.

In claim 28, "said set" lacks antecedent basis.

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**Supplemental Box**
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of Certain Documents Cited

1. Certain published documents (Rule 70.10)

| Application No Patent No. | Publication Date *(day/month/year)* | Filing Date *(day/month/year)* | Priority date (valid claim) *(day/month/year)* |
|---|---|---|---|
| None | None | None | None |

2. Non-written disclosures (Rule 70.9)

| Kind of non-written disclosure | Date of non-written disclosure *(day/month/year)* | Date of written disclosure referring to non-written disclosure *(day/month/year)* |
|---|---|---|
| None | None | None |

| INTERNATIONAL PRELIMINARY EXAMINATION REPORT | International application No. PCT/US99/28449 |
|---|---|

**Supplemental Box**
(To be used when the space in any of the preceding boxes is not sufficient)

### V. 2. Citations and Explanations:

Claims 1 and 2 lack novelty under PCT Article 33(2) as being anticipated by Nakata et al.

Regarding independent claim 1, Nakata et al. discloses step (c): "processing a group of adjacent pitch values and weighting them to compute a weighted average in order to compute the most probable value of pitch" - in order to select one pitch period from a plurality of extracted pitch period candidates, a smoothed average of the past pitch periods is calculated and it is used as a guide index for the selection (column 2, lines 63 to 68; column 4, line 66 to column 5, line 63: Figure 5).

Regarding claim 2, Nakata et al. extracts pitch for a speech signal.

Claims 22, 26 and 27 lack novelty under PCT Article 33(2) as being anticipated by Tanaka et al.

Regarding independent claim 22, Tanaka et al. discloses gain-shape vector quantization; an analysis-synthesis system is formed with analysis by evaluation unit 5, synthesis through synthesis filters 3i - 3n, and comparison with input speech signal at adder 12. (Column 3, Lines 8 to 61: Figure 2)

Regarding claim 26, Tanaka et al. discloses that each code book C contains a plurality (N) of shape vectors 13i that are produced in response to an index data. (Column 3, Lines 26 to 61)

Regarding claim 27, Tanaka et al. discloses a prediction filter portion 3 that compares the reproduced synthetic vector and a vector of practical speech input from an external unit at the second adder 12, thereby to find an error between the two; the result is input to evaluation unit 5 that selects plural combinations of optimum shape vectors from code book portion 1. (Column 3, Lines 47 to 67)

Claims 10 and 28 lack an inventive step under PCT Article 33(3) as being obvious over Kleijn ('595) in view of Tanaka et al.

Concerning claim 10, Kleijn ('595) suggests a gain shape codebook (column 15, lines 32 to 34), but does not expressly disclose analysis by synthesis vector quantization of the gain sequence. However, Tanaka et al. discloses gain-shape vector quantization where an analysis-synthesis system is formed with analysis by evaluation unit 5, synthesis through synthesis filters 3i - 3n, and comparison with input speech signal at adder 12. (Column 3, Lines 8 to 61: Figure 2) It would not have involved an inventive step to utilize the

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(To be used when the space in any of the preceding boxes is not sufficient)

gain-shape vector quantization method of Tanaka et al. in the waveform interpolation coder suggested by Kleijn ('595) for the purpose of decreasing the quantization distortion. (See Tanaka et al., Column 1, Line 65 to Column 2, Line 6)

Concerning claim 28, Tanaka et al. discloses gain-shape vector quantization, but does not say that the shape vectors are selected from a set of 1 to 50 values. However, Tanaka et al. does illustrate approximately 5-10 values of shape vectors (Figure 2), and Kleijn ('595) says that a shape quantizer for REW may have 8 shapes. (Column 13, Lines 17 to 36) It would not have involved an inventive step to choose 5-10 shapes for the code book 1 of shape vectors in the gain-shape vector quantization method of Tanaka et al. because Kleijn ('595) suggests that this is a reasonable number of shape vectors for prototype waveforms.

Response to Remarks:

Regarding claim 13, Applicant argues that the method focuses specifically on dispersion phase, and Kleijn ('595) does not provide a method for full quantization of the phase. However, the Specification does not state how dispersion phase quantization differs from the phase quantization of Kleijn ('595). Moreover, the disclosure of Kleijn ('595) is presumed to be enabling in describing quantization of phase spectra with an index ranging from 0 through K. (Column 14, Lines 36 to 46)

Applicant's remaining comments are moot in view of the new grounds of rejection over Nakata et al. and Tanaka et al. The new grounds of rejection were necessitated by Applicant's amendments.

-------------- NEW CITATIONS --------------

US 4,653,098 A (NAKATA et al.) 24 March 1987 (24.03.1987), see column 2, lines 63 to 68, column 4, line 66 to column 5, line 63.

THE CLAIMS:

1. A method for interpolative coding input signals said signals decomposed into or composed of a slowly evolving waveform and other attributes or components, the method incorporating at least one of the following steps:

(a) analysis-by-synthesis of the slowly evolving waveform such that it minimizes or reduces the effect of the non-ideal interpolation of a group of adjacent waveforms;

(b) analysis-by-synthesis quantization of the dispersion phase such that the linear shift phase attribute is reduced or eliminated from the quantization;

(c) processing a group of adjacent pitch values and weighting them to compute a weighted average in order to compute the most probable value of pitch.

(d) incorporating spectral and temporal pitch searches, such that the temporal search is performed at a different rate than the spectral search;

(e) incorporating temporal weighting in the analysis-by-synthesis vector-quantization of the gain sequence;

(f) quantizing adjacent values by analysis-by-synthesis vector-quantization without downsampling or interpolation of the gain values;

(g) incorporating switch prediction or switched filtering in the analysis-by-synthesis vector-quantization of the gain sequence;

(h) using a coder in which a plurality of bits therein are allocated to the vector-quantization of the dispersion phase of the slowly evolving waveform from which the linear shift attribute was reduced or removed; and

(i) pitch searching using varying boundaries of the summations used in computing the similarity or an equivalent distortion measure used for the pitch search.

2. The method of claim 1 in which said signal is speech.

3. The method of claim 1 in which said method incorporates each of steps (a) through (i).

4. The method of claim 1 in which in the step of analysis-by-synthesis vector-quantization of the slowly evolving waveform, distortion is reduced in the signal by obtaining the accumulated weighted distortion between a sequence of input waveforms and a sequence of quantized and interpolated waveforms.

5. The method of claim 1 including a system for providing at least one codebook containing magnitude and dispersion phase information for predetermined waveforms, and in which the step of analysis-by-synthesis quantization of the dispersion phase is conducted by crudely aligning the linear phase of one or the other of the input and output, then iteratively shifting said crudely aligned linear phase input or output, comparing the shifted input or output to a plurality of waveforms reconstructed from the magnitude and dispersion phase information contained in said at least one codebook, and selecting the reconstructed waveform that best matches one of the iteratively shifted inputs or outputs.

6. The method of claim 1 in which in the method of temporal domain searching the instantaneous pitch period in said step comprises defining boundaries of segments of said summations used to compute similarity or an equivalent distortion measure for pitch search, selecting the best boundary such that maximizing the similarity, or minimizing the distortion, measure by iteratively shifting and by changing the length of the segments used for the summations used in the measure computations.

7. The method of claim 1 in which the spectral domain pitch and temporal domain pitch searches are conducted at different rates.



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8. The method of claim 1 in which the step of the temporal weighting in the analysis-by-synthesis vector-quantization of the signal gain is changed as a function of time whereby to emphasize local high energy events in the input signal.

9. The method of claim 1 in which selection between the high and low correlation synthesis filters in the analysis-by-synthesis vector-quantization of the signal gain is made to maximize similarity or other meaningful objective between the input target gain vector and a reconstructed vector.

10. The method of claim 1 wherein each value of gain index in the analysis-by-synthesis vector-quantization of the gain sequence is used to obtain a plurality of shapes, each reconstructed from a predetermined codebook having a number of entries, and comparing said shapes to an input target vector and selecting the reconstructed shape that maximizes the similarity to the input target vector.

12. The method of quantizing waveforms by using the accumulated distortion between adjacent input waveforms to adjacent quantized and interpolated output waveforms, optionally using accumulated spectrally weighted distortion.

13. A method for interpolative coding input signals in which the signal decomposed into or composed of attributes or components one of which is a slowly evolving waveform, which has or from which one can extract a dispersion phase, the method incorporating analysis-by-synthesis quantization of the dispersion phase.

14. The method of claim 13 including providing at least one codebook containing magnitude and dispersion phase information for predetermined waveforms, crudely aligning the linear phase of the input, then iteratively



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shifting said crudely aligned linear phase input, and/or comparing the shifted input, or equivalently shifting the quantized vector, to a plurality of vectors reconstructed from the magnitude and dispersion phase information contained in said at least one codebook, and selecting the reconstructed vector that best matches the input vector or one of the iteratively shifted input vectors.

15. The method of claim 14 in which the average global distortion measure for a particular vector set M is:

$$\frac{1}{M} \sum_{m=\{Data\ Vectors\}} \frac{1}{K_m} \sum_{k=1}^{K_m} w_{kk,m} \left| r(k)_m - e^{j\hat{\varphi}(k)_m} \left|\hat{r}(k)\right|_m \right|^2$$

and including the step of minimizing the global distortion thereof by using the following formula for the k-th harmonic's phase for the j-th cluster:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m} \left|r(k)_m\right| \sin(\varphi(k)_m)}{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m} \left|r(k)_m\right| \cos(\varphi(k)_m)}\right]$$

16. The method of claim 14 in which the average global distortion measure for a particular vector set M is:

$$\frac{1}{M}\sum_{\substack{m=\{Data\\ Vectors\}}}\frac{1}{K_m}\sum_{k=1}^{K_m} w_{kk,m}\left|r(k)_m - e^{j\hat{\varphi}(k)_m}\left|\hat{r}(k)\right|_m\right|^2$$

and including the step of minimizing the global distortion thereof by using the following formula for the k-th harmonic's phase for the j-th cluster:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum_{m=\{j^{th}-cluster\}}\frac{1}{K_m}w_{kk,m}\left|\hat{r}(k)_m\right|\left|r(k)_m\right|\sin(\varphi(k)_m)}{\sum_{m=\{j^{th}-cluster\}}\frac{1}{K_m}w_{kk,m}\left|\hat{r}(k)_m\right|\left|r(k)_m\right|\cos(\varphi(k)_m)}\right]$$

17. A method for interpolative coding input signals, comprising using spectral and temporal pitch searches, computing a number of adjacent pitch values and optionallky some weight associated with their probability, and then computing the most probable pitch value by computing the weighted average pitch value using the above said weight.

18. The method of claim 17 in which in the method of searching the temporal domain pitch comprises defining a boundary for a segment used for the summations in the computed measure used for the pitch search, selecting the boundaries of the segment that maximize the similarity, or minimize the distortion measure, used for the pitch search, by iteratively shifting and expanding the segment and by shifting the segment.



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19. The method of claim 18 in which the method of searching the temporal domain pitch is in accordance with the formula:

$$P(n_i) = \underset{\tau,N_1,N_2}{\arg\max}\left\{ \rho(n_i,\tau,N_1,N_2) \right\} =$$

$$\underset{\tau,N_1,N_2}{\arg\max}\left\{ \frac{\sum_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n)s_w(n-\tau)}{\sqrt{\sum_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n)s_w(n)}\sqrt{\sum_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n-\tau)s_w(n-\tau)}} \right\}$$

where t is the shift in the segment, D is some incremental segment used in the summations for computational simplicity, and *Nj* is a number calculated for the codes.

20. A method for using a weighted average to compute one pitch value out of a set of pitch values, in accordance with the formula:

[ $$P_{mean} = \sum_{i=1}^{5}\rho(n_i)P(n_i) / \sum_{i=1}^{5}\rho(n_i)$$ ]

$$P_{mean} = \sum_{i=1}^{M}\rho(n_i)P(n_i) / \sum_{i=1}^{M}\rho(n_i)$$

where $M$ is the number of averaged pitch values and $\rho(n_i)$ $\rho(n_i)$ is the normalized correlation for $P(n_i)$.

21. The method of claim 19 in which the spectral domain pitch and temporal domain pitch searches in said step of locking onto the most probable pitch period of the signals are conducted respectively at 100 Hz and 500 Hz.

22. A method and a system for vector quantization of the signal gain sequence using analysis-by-synthesis, optionally using temporal weighting, and optionally using a switch predictive synthesis filter or predictor.

23. The method of claim 22 in which the temporal weighting is changed as a function of time whereby to emphasize local high energy events in the input signal.

24. The method of claim 22, comprising applying synthesis filter or predictor, which introduces selected high correlation or low correlation to a vector quantizer codebook in the analysis-by-synthesis vector-quantization of the signal gain sequence whereby to add selected self correlation to the codebook vectors.

25. The method of claim 24 in which selection between the high and low correlation synthesis filters or predictor is made to maximize similarity or other relevant measure between the signal vector and a reconstructed vector.

26. The method of claim 22, comprising using each value of gain index in the analysis-by-synthesis vector-quantization of the signal gain.

27. The method of claim 22 wherein each value of gain index is used to select from a plurality of shapes and associated predictors or filters, each of



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which is used to generate an output shape vector, and comparing the output shape vector to an input shape vector.

28. The method of claim 27 in which said set has predetermined number of values in the range of 1 to 50.

29. The method of claim 33 in which said set has predetermined number of values in the range of 1 to 50.

30. A method for quantization of a waveform phase, comprising removing the linear phase shift attribute, extracting and/or quantizing the dispersion phase attribute by at least one bit.

31. The method of claim 30 in which at least one bit is allocated to the dispersion phase.

32. A method for simplifying accumulated distortion between a set of adjacent input vectors, $r_{m2}$ to a set of quantized and interpolated vectors $\hat{\mathbf{r}}_M$:

$$D_{wI}(\hat{\mathbf{r}}_M, \{\mathbf{r}_m\}_{m=1}^{M+L-1}) = \begin{bmatrix} \sum_{m=1}^{M} [\mathbf{r}_m - \tilde{\mathbf{r}}_m]^H \mathbf{W}_m [\mathbf{r}_m - \tilde{\mathbf{r}}_m] \\ + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \left[\mathbf{r}_m - \tilde{\mathbf{r}}_M\right]^H \mathbf{W}_m \left[\mathbf{r}_m - \tilde{\mathbf{r}}_M\right] \end{bmatrix} \tag{1}$$

by an equivalent simple distortion between only one input and one optimized output vector:

$$D_W(\hat{\mathbf{r}}_M, \mathbf{r}_{M,opt}) = (\hat{\mathbf{r}}_M - \mathbf{r}_{M,opt})^H \mathbf{W}_{M,opt} (\hat{\mathbf{r}}_M - \mathbf{r}_{M,opt}) \tag{2}$$

where computing optimal vector $r_{M,opt}$ by:

$$\mathbf{r}_{M,opt} = \mathbf{W}_{M,opt}^{-1}\begin{bmatrix} \sum_{m=1}^{M} \alpha(t_m)\mathbf{W}_m\left[\mathbf{r}_m - [1-\alpha(t_m)]\hat{\mathbf{r}}_0\right] \\ + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \mathbf{W}_m \mathbf{r}_m \end{bmatrix} \quad (3)$$

and the respective weighting matrix $W_{M,opt}$ is given by:

$$\mathbf{W}_{M,opt} = \sum_{m=1}^{M} \alpha(t_m)^2 \mathbf{W}_m + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \mathbf{W}_m \quad (4)$$

33. A method and a system for quantizing waveform using the simplification method of claim 32 such that the respective quantized vector $\hat{\mathbf{r}}_M$ is given by:

$$\hat{\mathbf{r}}_M = \underset{\mathbf{r}'_i}{\operatorname{argmin}} \left\{ (\mathbf{r}'_i - \mathbf{r}_{M,opt})^H \mathbf{W}_{M,opt} (\mathbf{r}'_i - \mathbf{r}_{M,opt}) \right\} \quad (5)$$

34. The method of claim 17 in which in the method using the normalized autocorrelations obtained for each pitch value, or some function of the autocorrelation, as its associated probability weight used to compute the weighted average pitch value.



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# ¨PATENT COOPERATION TF \TY

From the INTERNATIONAL BUREAU

## PCT

**NOTIFICATION OF ELECTION**

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

| | |
|---|---|
| **Date of mailing** (day/month/year)<br>01 September 2000 (01.09.00) | |
| **International application No.**<br>PCT/US99/28449 | **Applicant's or agent's file reference**<br>1279-277 |
| **International filing date** (day/month/year)<br>01 December 1999 (01.12.99) | **Priority date** (day/month/year)<br>01 December 1998 (01.12.98) |
| **Applicant**<br>GOTTESMAN, Oded | |

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

24 May 2000 (24.05.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

| | |
|---|---|
| **The International Bureau of WIPO**<br>**34, chemin des Colombettes**<br>**1211 Geneva 20, Switzerland**<br>Facsimile No.: (41-22) 740.14.35 | Authorized officer<br>Zakaria EL KHODARY<br>Telephone No.: (41-22) 338.83.38 |

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/28449

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : G10L 19/00
US CL : 704/207, 220, 222

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 704/207, 216, 220, 222, 229, 230

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST, IEEE/IEE Electronic Library

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>—<br>Y | US 5,517,595 A (KLEIJN) 14 May 1996 (14.05.1996), column 2, lines 35 to 65; column 14, lines 8 to 48; column 7, lines 41 to 51; column 8, lines 8 to 38; column 10, line 51 to column 11, line 67. | 11, 12, 13, 17, 18, 22, 23, 26, 30<br>—<br>27, 28, 29, 31 |
| Y | US 5,086,471 A (TANAKA et al.) 04 February 1992 (04.02.1992), column 2, lines 11 to 42; column 6, lines 15 to 30; Figures 1, 2, 5A, 5B, 6. | 27, 28, 29, 31 |
| A | XYDEAS, C. et al. Source driven variable bit rate prototype interpolation coding. Conference Proceedings, 1996 IEEE International Conference on Acoustics, Speech, and Signal Processing. May, 1996, Vol. 1, pages 220-223. | 1-31 |
| A | PAPANASTASIOU, C., et al. Efficient mixed excitation models in LPC based prototype interpolation speech coders. 1997 IEEE International Conference on Acoustics, Speech, and Signal Processing. April 1997, Vol. 2, pages 1555-1558. | 1-31 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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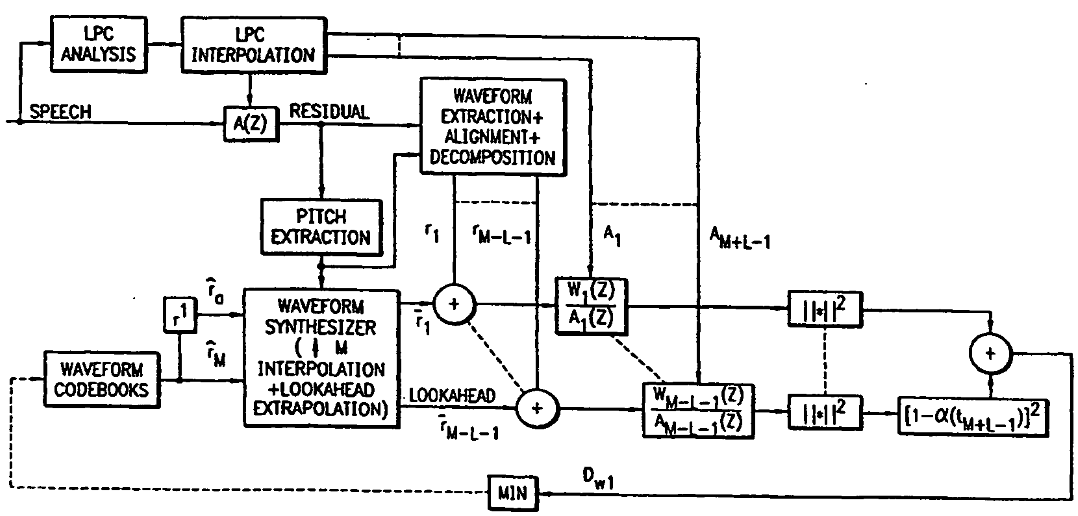
(54) Title: ENHANCED WAVEFORM INTERPOLATIVE CODER




(57) Abstract

An enhanced analysis-by-synthesis Waveform Interpolative speech coder able to operate at 4 kbps. Novel features include analysis-by-synthesis quantization of the slowly evolving waveform, analysis-by-synthesis vector quantization of the dispersion phase, a special pitch search for transitions, and switched-protective analysis-by synthesis gain vector quantization. Subjective quality tests indicate that it exceeds MPEG-4 at 4 kbps and of G.723.1 at 5.3 kbps, and it is slightly better than G.723.1 at 6.3 kbps.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

The Regents of the University of California;

Oded Gottesman

International Application No.: PCT/US99/28449

For: ENHANCED WAVEFORM INTERPOLATIVE CODER

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## SUBSTITUTE RESPONSE TO WRITTEN OPINION

Commissioner of Patents & Trademarks
Washington, D. C. 20231
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Sir:

This is a substitute response replacing the response to the written opinion of 2 March 2001 that was filed on 2 May 2001..

Claims 1,3, 4, 5, 6, 7, 9, 10, 12, 13, 14, 17, 18, 22, 24, 25, 27, 28, 29, and 31 have been amended, and Claims 32, 33 and 34 have been added. The changes are shown in the attached VERSION OF CLAIMS WITH MARKINGS TO SHOW CHANGES. Modified specification pages 2 and 9 are enclosing making the corrections suggested by the Examiner.

## REMARKS

The Kleijn reference does not teach or suggest any embodiments of the invention as will be discussed below.

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Referring to Claims 1(a) and 4, the instant AbS is between a sequence of input waveforms to sequence of quantized and interpolated waveforms, rather than between only one input to one output waveform (per frame) as in Kleijn. The AbS of the claims takes into considerations the effect of interpolating the waveforms, unlike Kleijn. The AbS of the claims is different from Kleijn's AbS.

Regarding Claims 1(b), 5 and 14, the waveform is shifted in order to eliminate the linear phase shift between the quantizer input to its output, which helps to eliminate the linear shift and to focus on the dispersion phase. In Kleijn, the shift is done in a different context for a completely different purpose, which is smoothing the characteristic waveform, and no phase quantization method or system is described in Kleijn, and no focus on the dispersion phase is suggested there.

The novelty of Claim 6 novelty is in the varying boundaries of the summations, in computing the distortion measure or an equivalent similarity measure, such as normalized correlation, used for the pitch search.

Regarding Claims 6 and 17, and 18, the varying boundaries we refer to are those used for the summations used in the computation of the similarity (or distortion) measure, while the boundaries mentioned in Kleijn are the extracted waveform's boundaries, a totally different subject and context.

Regarding Claims 10, 22, and 27, the methods here are not the same as in Kleijn. Kleijn suggests to quantize the SEW on a gain-shape product VQ, i.e. gain-shape-VQ applied to one SEW vector. Here we apply VQ to the gain sequence. These are two different subjects and context.

Regarding Claim 12, novelty is in using accumulated distortion for the quantization, while others used distortion between one input to one output vector.

Regarding Claim 13, the indexes 0-to-K in Kleijn refer to the level of voicing, periodicity, or the peakiness of the SEW waveform, and not to a full quantization of the phase which may produce changing phase even when the level of voicing is unchanged. Kleijn mentions the possibility of phase spectra quantization and doesn't provide any method or system to do it. The method of this invention focuses specifically on the dispersion phase attribute of the phase, and provides a method and a system to extract and to quantize the dispersion phase.

Regarding Claims 22 and 26, Kleijn doesn't perform Vector-Quantization of the gain (instead he uses down sampling and scalar quantizer), and we suggested

VQ of the gain using AbS and switch prediction. Kleijn doesn't use any temporal weighting nor does he use analysis-by-synthesis or switch prediction for the gain quantization.

Respectfully submitted,

May 4, 2001

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fixed phase vector for the slowly evolving waveform [Shoham, *supra*; Kleijn et al, *supra*; and Burnett et al, *supra*]. For example, in Kleijn et al, a fixed male speaker extracted phase was used. On the other hand, waveform coders such as CELP, by directly quantizing the waveform, implicitly allocate an excessive number of bits to the phase information - more than is perceptually required.

## SUMMARY OF THE INVENTION

The present invention overcomes the foregoing drawbacks by implementing a paradigm that incorporates analysis-by-synthesis (AbS) for parameter estimation, and a novel pitch search technique that is well suited for the non-stationary segments. In one embodiment, the invention provides a novel, efficient AbS vector quantization (VQ) encoding of the dispersion phase of the excitation signal to enhance the performance of the waveform interpolative (WI) coder at a very low bit-rate, which can be used for parametric coders as well as for waveform coders. The enhanced analysis-by-synthesis waveform interpolative (EWI) coder of this invention employs this scheme, which incorporates perceptual weighting and does not require any phase unwrapping.

The WI coders use non-ideal low-pass filters for downsampling and upsampling of the slowly evolving waveform (SEW). In another embodiment of the invention, a novel AbS SEW quantization scheme is provided, which takes the non-ideal filters into consideration. An improved match between reconstructed and original SEW is obtained, most notably in the transitions.

Pitch accuracy is crucial for high quality reproduced speech in WI coders. Still another embodiment of the invention provides a novel pitch search technique based on varying segment boundaries; it allows for locking onto the most probable pitch period during transitions or other segments with rapidly varying pitch.

Commonly in speech coding, the gain sequence is downsampled and interpolated. As a result it is often smeared during plosives and onsets. To alleviate this problem, a further embodiment of the invention provides a novel switched-predictive AbS gain VQ scheme based on temporal weighting.

The centroid equation [A. Gersho et al, "Vector Quantization and Signal Compression", Kluwer Academic Publishers, 1992] of the k-th harmonic's phase for the j-th cluster, which minimizes the global distortion in equation (11), is given by:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m} \left|\hat{r}(k)_m\right|\left|r(k)_m\right| \sin(\varphi(k)_m)}{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m} \left|\hat{r}(k)_m\right|\left|r(k)_m\right| \cos(\varphi(k)_m)}\right]$$

These centroid equations use trigonometric functions of the phase, and therefore do not require any phase unwrapping. It is possible to use $\left|r(k)_m\right|^2$ instead of $\left|\hat{r}(k)_m\right|\left|r(k)_m\right|$.

The phase vector's dimension depends on the pitch period and, therefore, a variable dimension VQ has been implemented. In the WI system the possible pitch period value was divided into eight ranges, and for each range of pitch period an optimal codebook was designed such that vectors of dimension smaller than the largest pitch period in each range are zero padded.

Pitch changes over time cause the quantizer to switch among the pitch-range codebooks. In order to achieve smooth phase variations whenever such switch occurs, overlapped training clusters were used.

The phase-quantization scheme has been implemented as a part of WI coder, and used to quantize the SEW phase. The objective performance of the suggested phase VQ has been tested under the following conditions:

- Phase Bits: 0-6 every 20ms, a bitrate of 0-300 bit/second.
- 8 pitch ranges were selected, and training has been performed for each range.
- Modified IRS (MIRS) filtered speech (Female+Male)
    - Training Set: 99,323 vectors.
    - Test Set: 83,099 vectors.
- Non-MIRS filtered speech (Female+Male)

VERSION OF CLAIMS WITH MARKINGS TO SHOW CHANGES

1. (Amended) A method for interpolative coding input signals [at low data rates in which there is significant pitch transitivity, and wherein said signals] said signals [may have] decomposed into or composed of a slowly evolving waveform and other attributes or components, the method incorporating at least one of the following steps:

(a) analysis-by-synthesis [vector-quantization] of the slowly evolving waveform such that it minimizes or reduces the effect of the non-ideal interpolation of a group of adjacent waveforms;

(b) analysis-by-synthesis quantization of the dispersion phase such that the linear shift phase attribute is reduced or eliminated from the quantization;

(c) processing a group of adjacent pitch values and weighting them to compute a weighted average in order to compute the most probable value of pitch.

[(c) locking onto the most probable pitch period of the signal using both a] (d) incorporating spectral [domain pitch search] and [a] temporal [domain] pitch [search] searches, such that the temporal search is performed at a different rate than the spectral search;

[(d)] (e) incorporating temporal weighting in the analysis-by-synthesis vector-quantization of the [signal] gain sequence;

[(e) applying both high correlation and low correlation synthesis filters to a vector quantizer codebook in the analysis-by-synthesis vector-quantization of the signal gain whereby to add self correlation to the codebook vectors;]

(f) [using each value of gain in the] quantizing adjacent values by analysis-by-synthesis vector-quantization without downsampling or interpolation of the [signal] gain values; [and]

(g) incorporating switch prediction or switched filtering in the analysis-by-synthesis vector-quantization of the gain sequence;

[(g)] (h) using a coder in which a plurality of bits therein are allocated to the vector-quantization of the dispersion phase of the slowly

evolving waveform phase from which the linear shift attribute was reduced or removed[.]; and

(i) pitch searching using varying boundaries of the summations used in computing the similarity or an equivalent distortion measure used for the pitch search.

2. The method of claim 1 in which said signal is speech.

3 (Amended) The method of claim 1 in which said method incorporates each of steps (a) through [(g)] (i).

4. (Amended) The method of claim 1 in which in the step of analysis-by-synthesis vector-quantization of the slowly evolving waveform, distortion is reduced in the signal by obtaining the accumulated weighted distortion between [an original] a sequence of input waveforms and a sequence of quantized and interpolated waveforms.

5. (Amended) The method of claim 1 including a system for providing at least one codebook containing magnitude and dispersion phase information for predetermined waveforms, and in which the step of analysis-by-synthesis quantization of the dispersion phase is conducted by crudely aligning the linear phase of one or the other of the input and output, then iteratively shifting said crudely aligned linear phase input or output, comparing the shifted input or output to a plurality of waveforms reconstructed from the magnitude and dispersion phase information contained in said at least one codebook, and selecting the reconstructed waveform that best matches one of the iteratively shifted inputs or outputs.

6. (Amended) The method of claim 1 in which in the method of [searching the] temporal domain searching the instantaneous pitch period in said step [of locking onto the most probable pitch period of the signal,] comprises defining [a boundary for a segment of said temporal domain pitch, maximizing the best boundary and maximizing the similarity by

iteratively shifting the segment, and by shrinking and expanding the segment] boundaries of segments of said summations used to compute similarity or an equivalent distortion measure for pitch search, selecting the best boundary such that maximizing the similarity, or minimizing the distortion, measure by iteratively shifting and by changing the length of the segments used for the summations used in the measure computations.

7. (Amended) The method of claim 1 in which the spectral domain pitch and temporal domain pitch searches[, in said step of locking onto the most probable pitch period of the signals,] are conducted [respectively at 100 Hz and 500 Hz] at different rates.

8. The method of claim 1 in which the step of the temporal weighting in the analysis-by-synthesis vector-quantization of the signal gain is changed as a function of time whereby to emphasize local high energy events in the input signal.

9. (Amended) The method of claim 1 in which selection between the high and low correlation synthesis filters in the analysis-by-synthesis vector-quantization of the signal gain is made to maximize similarity or other meaningful objective between the input target gain [waveform] vector and a [codebook waveform] reconstructed vector.

10. (Amended) The method of claim 1 wherein each value of gain in the analysis-by-synthesis vector-quantization of the signal gain is used to obtain a plurality of shapes, each composed of a predetermined codebook having a number of [values] entries, and comparing said shapes to [a] an input target vector [quantized codebook of shapes, each having said predetermined number of values] and selecting the reconstructed shape that maximizes the similarity to the input target vector.

12. (Amended) The method of [claim 11] quantizing waveforms [in which distortion is reduced in the signal] by [obtaining the] using the

accumulated [weighted] distortion between [an original sequence of] adjacent input waveforms to adjacent [and a sequence of] quantized and interpolated output waveforms, optionally using accumulated spectrally weighted distortion.

13. (Amended) A method for interpolative coding input signals [at low data speeds] in which the signal decomposed into or composed of attributes or components one of which is a slowly evolving waveform, [has a slowly evolving waveform] which has or from which one can extract [and] a [linear] dispersion phase, the method incorporating analysis-by-synthesis quantization of the dispersion phase.

14. (Amended) The method of claim 13 including providing at least one codebook containing magnitude and dispersion phase information for predetermined waveforms, crudely aligning the linear phase of the input, then iteratively shifting said crudely aligned linear phase input, and/or comparing the shifted input, or equivalently shifting the quantized vector, to a plurality of [waveforms] vectors reconstructed from the magnitude and dispersion phase information contained in said at least one codebook, and selecting the reconstructed [waveform] vector that best matches the input vector or one of the iteratively shifted input[s] vectors.

15. The method of claim 14 in which the average global distortion measure for a particular vector set M is:

$$\frac{1}{M}\sum_{m=\{Data\ Vectors\}}\frac{1}{K_m}\sum_{k=1}^{K_m} w_{kk,m}\left|r(k)_m - e^{j\hat{\varphi}(k)_m}\left|\hat{r}(k)\right|_m\right|^2$$

and including the step of minimizing the global distortion thereof by using the following formula for the k-th harmonic's phase for the j-th cluster:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m}\left|r(k)_m\right|\sin(\varphi(k)_m)}{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m}\left|r(k)_m\right|\cos(\varphi(k)_m)}\right]$$

16. The method of claim 14 in which the average global distortion measure for a particular vector set M is:

$$\frac{1}{M}\sum_{m=\{Data\ Vectors\}} \frac{1}{K_m}\sum_{k=1}^{K_m} w_{kk,m}\left|r(k)_m - e^{j\hat{\varphi}(k)_m}\left|\hat{r}(k)\right|_m\right|^2$$

and including the step of minimizing the global distortion thereof by using the following formula for the k-th harmonic's phase for the j-th cluster:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m}\left|\hat{r}(k)_m\right|\left|r(k)_m\right|\sin(\varphi(k)_m)}{\sum_{m=\{j^{th}-cluster\}} \frac{1}{K_m} w_{kk,m}\left|\hat{r}(k)_m\right|\left|r(k)_m\right|\cos(\varphi(k)_m)}\right]$$

17. (Amended) A method for interpolative coding input signals [at low data rates], comprising <u>using spectral and temporal pitch searches, computing a number of adjacent pitch values and optionally some weight associated with their probability, and</u> <u>then computing</u> [locking onto] the

most probable pitch [period of the signal using both a spectral domain pitch search and a temporal domain pitch search] value by computing the weighted average pitch value using the above said weight.

18. (Amended) The method of claim 17 in which in the method of searching the temporal domain pitch comprises defining a boundary for a segment [of said temporal domain pitch] used for the summations in the computed measure used for the pitch search, selecting the [length of the] boundaries of the segment that maximize the similarity, or minimize the distortion measure, used for the pitch search, by iteratively shifting and expanding the segment and by shifting the segment.

19. The method of claim 18 in which the method of searching the temporal domain pitch is in accordance with the formula:

$$P(n_i) = \underset{\tau, N_1, N_2}{\arg\max} \left\{ \rho(n_i, \tau, N_1, N_2) \right\} =$$

$$\underset{\tau, N_1, N_2}{\arg\max} \left\{ \frac{\sum\limits_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n) s_w(n-\tau)}{\sqrt{\sum\limits_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n) s_w(n)} \sqrt{\sum\limits_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n-\tau) s_w(n-\tau)}} \right\}$$

where t is the shift in the segment, D is some incremental segment used in the summations for computational simplicity, and Nj is a number calculated for the codes.

20. (Amended) [The] A method [of claim 19 including the step of obtaining the] for using a weighted average to compute one pitch value out of a set of pitch values, in accordance with the formula:

$$[ \qquad P_{mean} = \sum_{i=1}^{5} \rho(n_i) P(n_i) / \sum_{i=1}^{5} \rho(n_i) \qquad ]$$

$$P_{mean} = \sum_{i=1}^{M} \rho(n_i) P(n_i) / \sum_{i=1}^{M} \rho(n_i)$$

where M is the number of averaged pitch values and $\rho(n_i)$ $\rho(n_i)$ is the normalized correlation for $P(n_i)$.

21. The method of claim 19 in which the spectral domain pitch and temporal domain pitch searches in said step of locking onto the most probable pitch period of the signals are conducted respectively at 100 Hz and 500 Hz.

22. (Amended) A method and a system for [interpolative coding input signals at low data speeds, comprising incorporating temporal weighting in the] vector quantization of the signal gain sequence using analysis-by-synthesis [vector-quantization of the signal gain], optionally using temporal weighting, and optionally using a switch predictive synthesis filter or predictor.

23. The method of claim 22 in which the temporal weighting is changed as a function of time whereby to emphasize local high energy events in the input signal.

24. (Amended) [A] The method [for interpolative coding input signals at low data speeds] of claim 22, comprising applying synthesis filter or predictor,

which introduces selected [both] high correlation or [and] low correlation [synthesis filters] to a vector quantizer codebook in the analysis-by-synthesis vector-quantization of the signal gain sequence whereby to add selected self correlation to the codebook vectors.

25. (Amended) The method of claim 24 in which selection between the high and low correlation synthesis filters or predictor is made to maximize similarity or other relevant measure between the signal [waveform] vector and a [codebook waveform] reconstructed vector.

26. (Amended) [A] The method [for interpolative coding input signals at low data speeds] of claim 22, comprising using each value of gain index in the analysis-by-synthesis vector-quantization of the signal gain.

27. (Amended) The method of claim [26] 22 wherein each value of gain index is used to [obtain] select from a plurality of shapes and associated predictors or filters, each of which is used to generate an output shape vector [composed of a predetermined number of values], and comparing [said shapes] the output shape vector to [a vector quantized codebook of shapes, each having said predetermined number of values] an input shape vector.

28. (Amended) The method of claim 27 in which said set has predetermined number of values [is] in the range of [2] 1 to 50.

29. (Amended) The method of claim [28] 33 in which said set has predetermined number of values [is] in the range of [5] 1 to [20] 50.

30. (Amended) A method for [interpolative coding input signals at low data speeds in which said signals have a slowly evolving] quantization of a waveform phase, comprising [using a coder in which a plurality of bits therein are allocated to the slowly evolving waveform phase] removing the linear phase shift attribute, extracting and/or quantizing the dispersion phase attribute by at least one bit..

31. (Amended) The method of claim 30 in which [4 bits are] at least one bit is allocated to the [slowly evolving waveform phase in the coder] dispersion phase.

32.(New) A method for simplifying accumulated distortion between a set of adjacent input vectors, $r_{m2}$ to a set of quantized and interpolated vectors $\hat{\mathbf{r}}_M$

$$D_{wI}(\hat{\mathbf{r}}_M, \{\mathbf{r}_m\}_{m=1}^{M+L-1}) = \begin{bmatrix} \sum_{m=1}^{M} [\mathbf{r}_m - \tilde{\mathbf{r}}_m]^H \mathbf{W}_m [\mathbf{r}_m - \tilde{\mathbf{r}}_m] \\ + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 [\mathbf{r}_m - \tilde{\mathbf{r}}_M]^H \mathbf{W}_m [\mathbf{r}_m - \tilde{\mathbf{r}}_M] \end{bmatrix} \quad (1)$$

by an equivalent simple distortion between only one input and one optimized output vector:

$$D_w(\hat{\mathbf{r}}_M, \mathbf{r}_{M,opt}) = (\hat{\mathbf{r}}_M - \mathbf{r}_{M,opt})^H \mathbf{W}_{M,opt} (\hat{\mathbf{r}}_M - \mathbf{r}_{M,opt}) \quad (2)$$

where computing optimal vector $r_{M,opt}$ by:

$$\mathbf{r}_{M,opt} = \mathbf{W}_{M,opt}^{-1} \begin{bmatrix} \sum_{m=1}^{M} \alpha(t_m) \mathbf{W}_m [\mathbf{r}_m - [1-\alpha(t_m)] \hat{\mathbf{r}}_0] \\ + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \mathbf{W}_m \mathbf{r}_m \end{bmatrix} \quad (3)$$

and the respective weighting matrix $W_{M,opt}$ is given by:

$$\mathbf{W}_{M,opt} = \sum_{m=1}^{M} \alpha(t_m)^2 \mathbf{W}_m + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \mathbf{W}_m \tag{4}$$

33. (New) A method and a system for quantizing waveform using the simplification method of claim 32 such that the respective quantized vector $\hat{\mathbf{r}}_M$ is given by:

$$\hat{\mathbf{r}}_M = \underset{\mathbf{r}'_i}{\operatorname{argmin}} \left\{ (\mathbf{r}'_i - \mathbf{r}_{M,opt})^H \mathbf{W}_{M,opt} (\mathbf{r}'_i - \mathbf{r}_{M,opt}) \right\} \tag{5}$$

34. (New) The method of claim 17 in which in the method using the normalized autocorrelations obtained for each pitch value, or some function of the autocorrelation, as its associated probability weight used to compute the weighted average pitch value.

THE CLAIMS:

1. A method for interpolative coding input signals said signals decomposed into or composed of a slowly evolving waveform and other attributes or components, the method incorporating at least one of the following steps:

(a) analysis-by-synthesis of the slowly evolving waveform such that it minimizes or reduces the effect of the non-ideal interpolation of a group of adjacent waveforms;

(b) analysis-by-synthesis quantization of the dispersion phase such that the linear shift phase attribute is reduced or eliminated from the quantization;

(c) processing a group of adjacent pitch values and weighting them to compute a weighted average in order to compute the most probable value of pitch.

(d) incorporating spectral and temporal pitch searches, such that the temporal search is performed at a different rate than the spectral search;

(e) incorporating temporal weighting in the analysis-by-synthesis vector-quantization of the gain sequence;

(f) quantizing adjacent values by analysis-by-synthesis vector-quantization without downsampling or interpolation of the gain values;

(g) incorporating switch prediction or switched filtering in the analysis-by-synthesis vector-quantization of the gain sequence;

(h) using a coder in which a plurality of bits therein are allocated to the vector-quantization of the dispersion phase of the slowly evolving waveform from which the linear shift attribute was reduced or removed; and

(i) pitch searching using varying boundaries of the summations used in computing the similarity or an equivalent distortion measure used for the pitch search.

2. The method of claim 1 in which said signal is speech.

3. _The method of claim 1 in which said method incorporates each of steps (a) through (i).

4. The method of claim 1 in which in the step of analysis-by-synthesis vector-quantization of the slowly evolving waveform, distortion is reduced in the signal by obtaining the accumulated weighted distortion between a sequence of input waveforms and a sequence of quantized and interpolated waveforms.

5. The method of claim 1 including a system for providing at least one codebook containing magnitude and dispersion phase information for predetermined waveforms, and in which the step of analysis-by-synthesis quantization of the dispersion phase is conducted by crudely aligning the linear phase of one or the other of the input and output, then iteratively shifting said crudely aligned linear phase input or output, comparing the shifted input or output to a plurality of waveforms reconstructed from the magnitude and dispersion phase information contained in said at least one codebook, and selecting the reconstructed waveform that best matches one of the iteratively shifted inputs or outputs.

6. The method of claim 1 in which in the method of temporal domain searching the instantaneous pitch period in said step comprises defining boundaries of segments of said summations used to compute similarity or an equivalent distortion measure for pitch search, selecting the best boundary such that maximizing the similarity, or minimizing the distortion, measure by iteratively shifting and by changing the length of the segments used for the summations used in the measure computations.

7. The method of claim 1 in which the spectral domain pitch and temporal domain pitch searches are conducted at different rates.

8. - The method of claim 1 in which the step of the temporal weighting in the analysis-by-synthesis vector-quantization of the signal gain is changed as a function of time whereby to emphasize local high energy events in the input signal.

9. The method of claim 1 in which selection between the high and low correlation synthesis filters in the analysis-by-synthesis vector-quantization of the signal gain is made to maximize similarity or other meaningful objective between the input target gain vector and a reconstructed vector.

10. The method of claim 1 wherein each value of gain index in the analysis-by-synthesis vector-quantization of the gain sequence is used to obtain a plurality of shapes, each reconstructed from a predetermined codebook having a number of entries, and comparing said shapes to an input target vector and selecting the reconstructed shape that maximizes the similarity to the input target vector.

12. The method of quantizing waveforms by using the accumulated distortion between adjacent input waveforms to adjacent quantized and interpolated output waveforms, optionally using accumulated spectrally weighted distortion.

13. A method for interpolative coding input signals in which the signal decomposed into or composed of attributes or components one of which is a slowly evolving waveform, which has or from which one can extract a dispersion phase, the method incorporating analysis-by-synthesis quantization of the dispersion phase.

14. The method of claim 13 including providing at least one codebook containing magnitude and dispersion phase information for predetermined waveforms, crudely aligning the linear phase of the input, then iteratively

shifting said crudely aligned linear phase input, and/or comparing the shifted input, or equivalently shifting the quantized vector, to a plurality of vectors reconstructed from the magnitude and dispersion phase information contained in said at least one codebook, and selecting the reconstructed vector that best matches the input vector or one of the iteratively shifted input vectors.

15. The method of claim 14 in which the average global distortion measure for a particular vector set M is:

$$\frac{1}{M}\sum_{\substack{m=\{Data\\Vectors\}}}\frac{1}{K_m}\sum_{k=1}^{K_m} w_{kk,m}\left|r(k)_m - e^{j\hat{\varphi}(k)_m}\left|\hat{r}(k)\right|_m\right|^2$$

and including the step of minimizing the global distortion thereof by using the following formula for the k-th harmonic's phase for the j-th cluster:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum\limits_{m=\{j^{th}-cluster\}}\frac{1}{K_m} w_{kk,m}\left|r(k)_m\right|\sin(\varphi(k)_m)}{\sum\limits_{m=\{j^{th}-cluster\}}\frac{1}{K_m} w_{kk,m}\left|r(k)_m\right|\cos(\varphi(k)_m)}\right]$$

16. The method of claim 14 in which the average global distortion measure for a particular vector set M is:

$$\frac{1}{M}\sum_{\substack{m=\{Data\\ Vectors\}}}\frac{1}{K_m}\sum_{k=1}^{K_m} w_{kk,m}\left|r(k)_m - e^{j\hat{\varphi}(k)_m}\left|\hat{r}(k)\right|_m\right|^2$$

and including the step of minimizing the global distortion thereof by using the following formula for the k-th harmonic's phase for the j-th cluster:

$$\hat{\varphi}(k)_{j^{th}-cluster} = \operatorname{atan}\left[\frac{\sum_{m=\{j^{th}-cluster\}}\frac{1}{K_m}w_{kk,m}\left|\hat{r}(k)_m\right|\left|r(k)_m\right|\sin(\varphi(k)_m)}{\sum_{m=\{j^{th}-cluster\}}\frac{1}{K_m}w_{kk,m}\left|\hat{r}(k)_m\right|\left|r(k)_m\right|\cos(\varphi(k)_m)}\right]$$

17. A method for interpolative coding input signals, comprising using spectral and temporal pitch searches, computing a number of adjacent pitch values and optionallky some weight associated with their probability, and then computing the most probable pitch value by computing the weighted average pitch value using the above said weight.

18. The method of claim 17 in which in the method of searching the temporal domain pitch comprises defining a boundary for a segment used for the summations in the computed measure used for the pitch search, selecting the boundaries of the segment that maximize the similarity, or minimize the distortion measure, used for the pitch search, by iteratively shifting and expanding the segment and by shifting the segment.

19. -The method of claim 18 in which the method of searching the temporal domain pitch is in accordance with the formula:

$$P(n_i) = \underset{\tau, N_1, N_2}{\arg\max}\left\{ \rho(n_i, \tau, N_1, N_2) \right\} =$$

$$\underset{\tau, N_1, N_2}{\arg\max}\left\{ \frac{\sum_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n)s_w(n-\tau)}{\sqrt{\sum_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n)s_w(n)}\sqrt{\sum_{n=n_i-N_1\Delta}^{n_i+\tau+N_2\Delta} s_w(n-\tau)s_w(n-\tau)}} \right\}$$

where t is the shift in the segment, D is some incremental segment used in the summations for computational simplicity, and *Nj* is a number calculated for the codes.

20. A method for using a weighted average to compute one pitch value out of a set of pitch values, in accordance with the formula:

[ $$P_{mean} = \sum_{i=1}^{5} \rho(n_i) P(n_i) / \sum_{i=1}^{5} \rho(n_i)$$ ]

$$P_{mean} = \sum_{i=1}^{M} \rho(n_i) P(n_i) / \sum_{i=1}^{M} \rho(n_i)$$

where $M$ is the number of averaged pitch values and $\rho(n_i)$ $\rho(n_i)$ is the normalized correlation for $P(n_i)$.

21. The method of claim 19 in which the spectral domain pitch and temporal domain pitch searches in said step of locking onto the most probable pitch period of the signals are conducted respectively at 100 Hz and 500 Hz.

22. A method and a system for vector quantization of the signal gain sequence using analysis-by-synthesis, optionally using temporal weighting, and optionally using a switch predictive synthesis filter or predictor.

23. The method of claim 22 in which the temporal weighting is changed as a function of time whereby to emphasize local high energy events in the input signal.

24. The method of claim 22, comprising applying synthesis filter or predictor, which introduces selected high correlation or low correlation to a vector quantizer codebook in the analysis-by-synthesis vector-quantization of the signal gain sequence whereby to add selected self correlation to the codebook vectors.

25. The method of claim 24 in which selection between the high and low correlation synthesis filters or predictor is made to maximize similarity or other relevant measure between the signal vector and a reconstructed vector.

26. The method of claim 22, comprising using each value of gain index in the analysis-by-synthesis vector-quantization of the signal gain.

27. The method of claim 22 wherein each value of gain index is used to select from a plurality of shapes and associated predictors or filters, each of

which-is used to generate an output shape vector, and comparing the output shape vector to an input shape vector.

28. The method of claim 27 in which said set has predetermined number of values in the range of 1 to 50.

29. The method of claim 33 in which said set has predetermined number of values in the range of 1 to 50.

30. A method for quantization of a waveform phase, comprising removing the linear phase shift attribute, extracting and/or quantizing the dispersion phase attribute by at least one bit.

31. The method of claim 30 in which at least one bit is allocated to the dispersion phase.

32. A method for simplifying accumulated distortion between a set of adjacent input vectors, $r_{m2}$ to a set of quantized and interpolated vectors $\hat{\mathbf{r}}_M$:

$$D_{wI}(\hat{\mathbf{r}}_M,\{\mathbf{r}_m\}_{m=1}^{M+L-1})=\begin{bmatrix}\sum_{m=1}^{M}[\mathbf{r}_m-\tilde{\mathbf{r}}_m]^H\mathbf{W}_m[\mathbf{r}_m-\tilde{\mathbf{r}}_m]\\+\sum_{m=M+1}^{M+L-1}[1-\alpha(t_m)]^2\left[\mathbf{r}_m-\tilde{\mathbf{r}}_M\right]^H\mathbf{W}_m\left[\mathbf{r}_m-\tilde{\mathbf{r}}_M\right]\end{bmatrix} \quad (1)$$

by an equivalent simple distortion between only one input and one optimized output vector:

$$D_W(\hat{\mathbf{r}}_M,\mathbf{r}_{M,opt})=(\hat{\mathbf{r}}_M-\mathbf{r}_{M,opt})^H\mathbf{W}_{M,opt}(\hat{\mathbf{r}}_M-\mathbf{r}_{M,opt}) \quad (2)$$

where computing optimal vector $r_{M,opt}$ by:

$$\mathbf{r}_{M,opt} = \mathbf{W}_{M,opt}^{-1} \left[ \begin{array}{l} \sum_{m=1}^{M} \alpha(t_m)\mathbf{W}_m \left[ \mathbf{r}_m - [1-\alpha(t_m)]\hat{\mathbf{r}}_0 \right] \\ + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \mathbf{W}_m \mathbf{r}_m \end{array} \right] \tag{3}$$

and the respective weighting matrix $W_{M,opt}$ is given by:

$$\mathbf{W}_{M,opt} = \sum_{m=1}^{M} \alpha(t_m)^2 \mathbf{W}_m + \sum_{m=M+1}^{M+L-1} [1-\alpha(t_m)]^2 \mathbf{W}_m \tag{4}$$

33. A method and a system for quantizing waveform using the simplification method of claim 32 such that the respective quantized vector $\hat{\mathbf{r}}_M$ is given by:

$$\hat{\mathbf{r}}_M = \underset{\mathbf{r}'_i}{\operatorname{argmin}} \left\{ (\mathbf{r}'_i - \mathbf{r}_{M,opt})^H \mathbf{W}_{M,opt} (\mathbf{r}'_i - \mathbf{r}_{M,opt}) \right\} \tag{5}$$

34. The method of claim 17 in which in the method using the normalized autocorrelations obtained for each pitch value, or some function of the autocorrelation, as its associated probability weight used to compute the weighted average pitch value.